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Department of Agriculture and Fisheries for Scotland in Association with The Spey District Salmon Fishery Board

The Movements of Adult Salmon within the River Spey

Scottish Fisheries Research Report Number 41, 1989
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Foreword

In 1988, a research project was initiated by the Spey District Salmon Fishery Board in conjunction with the Marine Laboratory, Aberdeen, of the Department of Agriculture and Fisheries for Scotland. The project was established to provide better understanding of factors affecting the spring run of salmon on the Spey. As a first step in achieving this objective, the differences in behaviour shown by fish entering the river at different times of the year were investigated, starting with an examination of the feasibility of radio tracking fish within the extensive Spey system. In the event, through good fortune, the choice of an active researcher, and considerable co-operation from our several sponsors, the project saw the successful tagging and tracking of 24 fish in the first year. Indeed, the initial results have been so encouraging that the decision was taken to publish them in full in this special *Scottish Fisheries Research Report.*

The results show very clear differences in the behaviour of fish entering the Spey at different times of the year. Earlier fish move long distances up stream to spawn, whereas later fish remain in the lower reaches. This finding was not in itself unexpected, but what was surprising was the discovery that the fish spent very long periods at a series of stopping places. The study has indicated how important the various holding pools within the river are to migrating salmon.

Further studies will focus on the behaviour of the early spring fish and efforts have already started to mount an active programme of tracking in 1989.

The initial success of these studies owes a great deal to a small number of of sponsors. We would like to express our gratitude to:—

The Highlands and Islands Development Board
The Crown Estate Commissioners
The MacRobert Trusts
The Atlantic Salmon Trust Ltd
Baxters of Speyside Ltd
Eagle Star Insurance Company Ltd
Stakis PLC
Walkers Shortbread Limited of Aberlour.

Finally, we would like to record our thanks to Robert Laughton, the author of this report, for his strong committment to the study.

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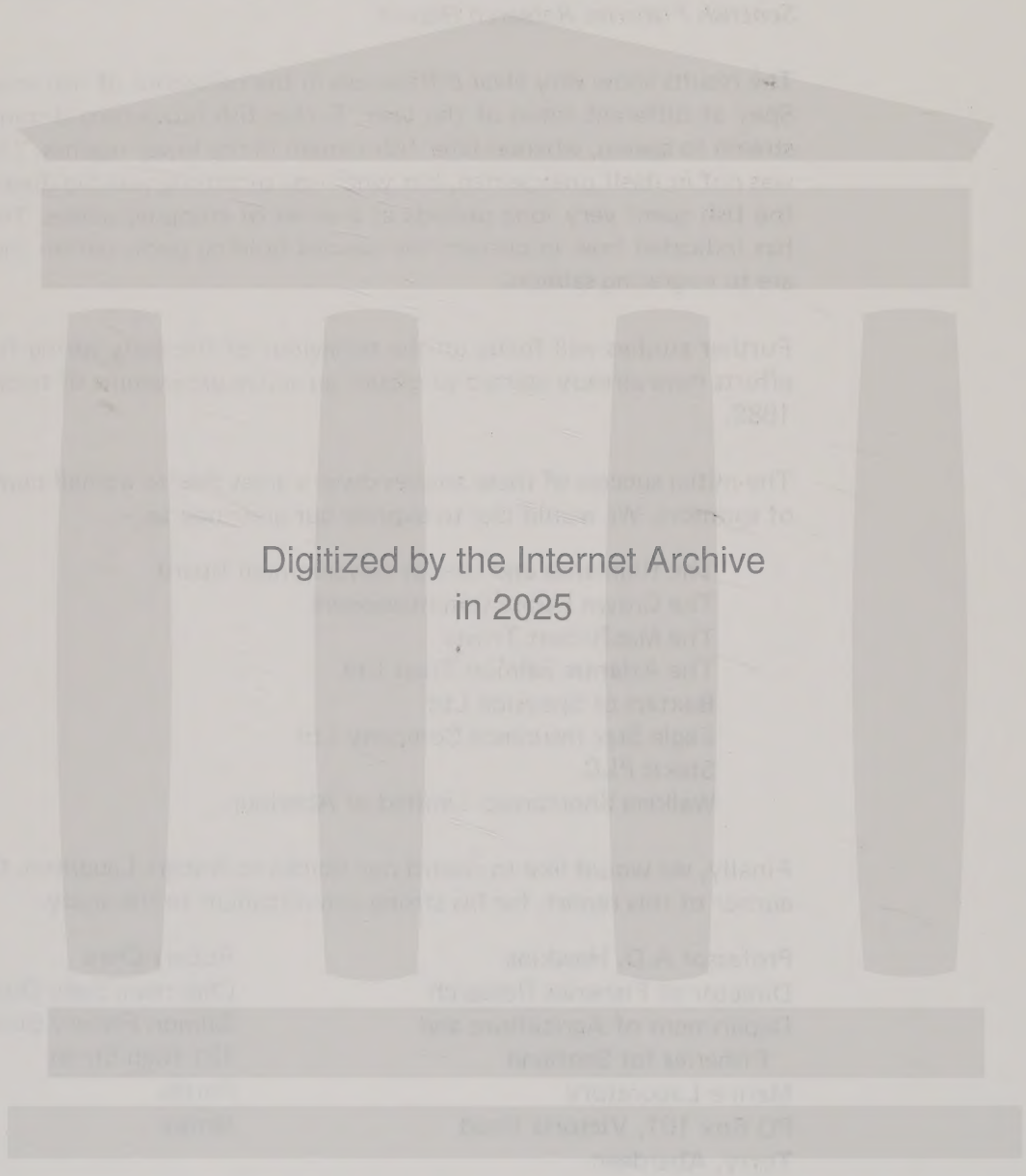

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The Movements of Adult Salmon within the River Spey

Robert Laughton*

Marine Laboratory, Aberdeen

***Employed by the Spey District Salmon Fishery Board.**

Introduction

Adult salmon, *Salmo salar* L., may return to the River Spey in north-east Scotland in any month of the year. The rod fishery takes place in the spring and summer and mainly exploits fish which have returned after several years in the sea (multi-sea-winter salmon). Grilse (one-sea-winter fish) become increasingly important in the catch of fresh-run fish from about May onwards (Shearer, 1988).

In common with a number of the larger east coast rivers there has recently been a decline in the rod catch of spring fish on the Spey and an increase in the grilse catch (Shearer, 1988). The reasons for this change are not clear. Spring fish, from their high fresh-water ages and wide distribution within the river on their return, are believed to originate in the upper reaches and tributaries of the river, where fresh-water development is slow. However, very little direct information is available on the differences in migratory behaviour and spawning distribution of the different seasonal classes of fish entering the river. It is this problem that the present study was set up to address.

The labelling and following of fish by means of transmitting tags has recently become a useful and widely used tool for determining their migration patterns (Hawkins and Urquhart, 1983). In the sea, acoustic tags, transmitting at ultrasonic frequencies, have been used to follow the coastal movements of returning salmon (Hawkins, Urquhart and Shearer 1979), and to examine the progress of fish through estuaries (Stasko, 1975; Brawn, 1982; Solomon and Potter, 1988). the Up-stream migrations of salmon within the main river itself have been studied by means of radio-tags (McLeave, Power and Rommel, 1978; Hawkins and Smith, 1986; Potter, 1988). In addition, with more complex telemetry tags it has proved possible to monitor the environment surrounding the migrating fish, for example, the dissolved oxygen levels (Priede, Solbé, Nott, O'Grady and Cragg-Hine, 1988).

With current changes in land use within upland areas, the increasing demand for drinking water, and other commercial and urban developments, rivers are coming under increasing pressure. Water abstraction, for example, at some levels in the river, may have an adverse effect upon the ascent of salmon to their spawning grounds. Changes in land use, and especially the changes in land drainage regimes accompanying afforestation or de-afforestation, may result in a changing quantity and patterns of water flow and increased silting within the smaller tributaries used by salmon for spawning. Establishing the behavioural requirements of salmon moving to their spawning grounds in the river is therefore a timely objective.

In this report, the movements of returning adult salmon within the river Spey are described. The study commenced at the end of April 1988 and continued into the spawning season in November of the same year. Though the main spring run was missed, several of the earlier tagged fish were multi-sea-winter salmon and represented the tail-end of the spring run and beginning of the summer run. Later, both early and late running grilse were tagged for comparison. Throughout the year attention was paid to the passage of salmon through the lower reaches of the Spey, and in particular to the influence of river flow upon the subsequent movements of the fish.

Methods

Fish Capture and Tagging

The salmon used for radio tracking were obtained from the net and coble fishery operated by the Crown Estate Commissioners in the lower reaches of the river Spey, below Fochabers (Fig. 1).

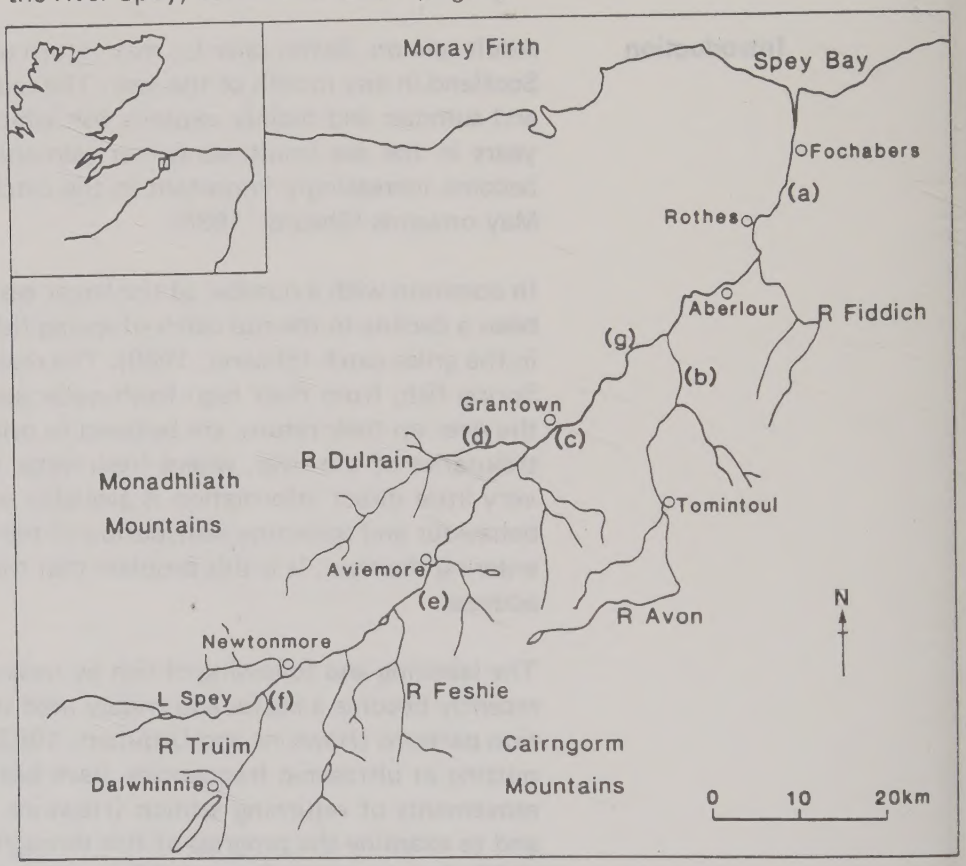

Figure 1. North East River Purification Board's Water Monitoring stations: (a) Boat o' Brig, (b) Delnashaugh, River Avon, (c) Grantown, (d) Balnaan, River Dulnain, (e) Kinrara, (f) Invertruim. Also shown is the Tulchan Hatchery (g) which supplied daily river temperatures.

Fish carrying sea lice were selected and quickly removed from the net to a holding tank. Each salmon was lightly anaesthetised using a solution of approximately 1 : 10,000 MS222 (Sandoz) in river water, the fork length was measured, a scale sample obtained for age determination at a later date and a yellow plastic Floy tag inserted in the dorsal musculature immediately below the dorsal fin. Where possible the sex was also determined from the external appearance of the fish.

The radio tag was gently inserted through the mouth into the stomach by means of a perspex tube. After insertion of the tag the fish was returned to the river to recover, and once the fish was able to maintain itself in an upright position and began to swim actively it was released.

The radio tags

The radio tags were supplied by the Ministry of Agriculture, Fisheries and Food (MAFF) Fisheries Directorate at Lowestoft, England. They transmitted brief signals (50 ms duration) at a nominal frequency of 174 MHz, and were powered by a Lithium cell. The transmitting circuit, battery and antenna were encapsulated within a polycarbonate shell. Overall dimensions were 54 mm by 16 mm diameter with hemispherical ends. The tags weighed approximately 14 g in air and 4 g in water.

Each tag operated at a particular frequency and pulse repetition rate, allowing individual fish to be identified. The life expectancy for each transmitter was approximately 9 months.

Fish tracking

After release, the salmon were tracked from the river bank using a hand held antenna and Yaesu FT 290R radio receiver pre-tuned to 10 different radio frequencies. The daily positions of each fish were recorded as Ordnance Survey co-ordinates, to the nearest 10 m, and these observations logged. Automatic listening stations (Argus Electronics) able to scan through 10 different frequencies every five minutes were positioned along the bank to aid tracking. These stations were able to record the passage of fish past particular points in the river, or could be placed alongside a stationary fish to record the time of leaving that position. Further details of the methods for tracking fish are given by Solomon and Storeton-West (1983) and Hawkins and Smith (1986).

Additional tracking was undertaken by means of a Cessna 172 single engined high wing monoplane equipped with a radio receiver and dipole antenna.

The co-ordinates obtained for each fish position were transferred to the main VAX computer in the Marine Laboratory, Aberdeen. The distances up-stream for each fish position, measured along the mid-line of the river, were calculated and stored in the computer.

All locations quoted in this paper are given in kilometres up stream from the mouth of the Spey, eg Fochabers (7).

Ancillary Measurements

Throughout the year, water flow and quality are routinely monitored by the North East River Purification Board. Metering stations are operated along the main stem and many of the major tributaries. Hourly flow data were made available from several stations, including Boat o'Brig, Grantown-on-Spey, Kinrara and Invertruim on the main river. Flow rates from Delnashaugh on the River Avon and Balnaan on the River Dulnain were also examined. The positions of these stations along the river are shown in Figure 1.

Data on the daily temperature of the main river were supplied by the Tulchan hatchery (Fig. 1), where water temperature is routinely recorded each morning at 08.30 h GMT.

The River Spey

The river Spey is one of the largest rivers in Scotland, having a total catchment of 2,988 km^2 (1,154 square miles), (Goody, 1988). In size, it is rivalled only by the Tay and the Tweed.

From its source at Loch Spey in the Cairngorm mountains, the river descends 157 km (97 miles) to the Moray Firth at Spey Bay. Apart from Spey Dam, operated by British Alcan in the upper reaches near Laggan, there are no obstructions along the main stem.

With numerous burns and tributaries draining a large expanse of the Cairngorms and Monadhliath Mountains, there is scope for considerable variation in the volume of water making its way to Speymouth. Like the Aberdeenshire Dee, the Spey is an 'alpine' river, with high plateaus sustaining a high flow from snow melt into May and June. Records of spates from heavy rain or snowmelt are numerous. The most famous spate resulted in the great flood of 1829 when large areas of the Spey valley were submerged. More recently a flood of 1,675 m^3s^{-1} in August 1970 caused significant damage in the lower reaches of the river. In some areas, particularly the lower reaches, the river is prone to change its course (Inglis, McEwen and MacLean, 1988). Such changes may well influence the movements of salmon, and where they rest.

Most major tributaries entering the Spey, the Feshie, Truim and Dulnain, do so in the higher reaches (Fig. 1). The exception is the Avon. This large, well-fished river enters the main stem at Ballindaloch, some 50 km up stream from Speymouth. Apart from the larger tributaries a multitude of smaller burns flow into the river. Some of these also support small spawning populations of salmon.

In common with many other Highland rivers, the waters of the Spey are low in nutrients (oligotrophic) and characteristically clear except at times of spate. The river has remained fairly free from pollution in recent times despite the distilling industry, farming and tourism (Lambart and Little, 1988).

Traditionally, the Spey has been a productive salmon river, rivalled in the United Kingdom only by the Dee, Tay and Tweed. A net and coble fishery has been operated in the lower reaches of the Spey for several centuries. Towards the end of the 18th century more than 130 men were employed during the fishing season to operate nets within the river and along the adjacent coast. In 1987 there was only one full time crew of nine men (Anon, 1987). A second crew was employed during the peak months of July and August.

For tracking purposes, ready access to the river is possible as far as Aviemore from at least one river bank using either the main public roads or estate tracks. Beyond Aviemore the river is often well away from the road and access can be difficult. Use was made of the light aircraft in searching for tagged fish in these areas.

Results

From April to August 1988, 24 fish were radio tagged and released into the river Spey. This total comprised 13 salmon and 11 grilse. Details of these fish tagged are presented in Table I.

Of the total 24, 10 fish were tracked successfully to spawning, two were recaptured by rod, six returned to sea, and the remaining six were lost, apparently owing to tag failure or other reasons.

For ease of presentation the fish have been divided into three seasonal groups. The first contains the 10 salmon released in late April and early May; the second, the three salmon and one grilse released during low water conditions in June; and the third the 10 grilse released in August.

Table I Details of the fish tagged and released into the Spey in 1988. Where the age of the fish is given, the first figure is the number of years spent in fresh water before migrating to the sea as a smolt; the next figure is the maiden sea age of the fish

Fish No	Release Date	Type	Age	Length (cm)	Sex	Floy Tag	Radio Tag	Comments
1	27.4	Salmon	2.2.1	75.0	M	24233	B014	Entered R. Dulnain 6.10
2	27.4	Salmon	–	78.0	–	24234	B015	Tag failed at Tulchan Hatchery 17.6
3	29.4	Salmon	2.2.1	79.0	–	24235	B023	Lost at Grantown Bridge 12 5
4	29.4	Salmon	3.2.1	76.5	–	24236	B016	Tag failure at Ordiequish 9.8
5	29.4	Salmon	2.2.1	77.5	–	24237	B017	Rod caught at Arndilly 5.5
6	29.4	Salmon	3.2.1	78.5	–	24238	B024	Tag failed at Dulnain Mouth 15 9
7	13.5	Salmon	2.2.1	76.5	–	24239	B030	Left river 24.5
8	13.5	Salmon	3.2.1	76.5	–	24241	B021	Caught at Grantown 5.9
9	13.5	Salmon	–	73.0	–	24242	B022	Left river 24.5
10	13.5	Salmon	2.2.1	80.5	–	24243	B029	Left river 24.5
11	20.6	Salmon	–	66.0	M	24245	B172	Lost or left river 19.8
12	20.6	Salmon	–	72.0	–	24247	B020	Spawned Upper Arndilly 4.12
13	24.6	Grilse	3.1.1	68.0	–	24248	B025	Spawned Newtonmore area 7.11
14	24.6	Salmon	–	81.0	–	24249	B008	Lost in R. Avon possible tag failure 14.7
15	5.8	Grilse	2.1.1	63.0	–	24275	B026	Baxters 4.12
16	5.8	Grilse	–	72.0	–	24277	B108	Left river 12.8
17	5.8	Grilse	–	70.0	–	24278	B105	Spawned Brae Island 4.12
18	5.8	Grilse	–	70.5	–	24279	B104	Spawned Orton Bothy 14 11
19	5.8	Grilse	–	67.0	–	24284	B094	Left river 14.9
20	12.8	Grilse	–	64.0	–	24285	B027	Spawned Rothes 4.12
21	12.8	Grilse	–	69.5	M	24286	B182	Spawned Knockando – Avonmouth 29.11
22	12;8	Grilse	3.1.1	67.0	F	24287	B102	Spawned Delfur 4.12
23	12.8	Grilse	3.1.1	63.5	–	24290	B098	Spawned Brae 4.12
24	12.8	Grilse	3.1.1	64.0	F	24291	B106	Left river 17.8

Fishes F1–10

The initial 10 salmon were released over three days, 27 April, 29 April and 13 May.

Fishes F1, F3 and F6 showed a rapid up-stream migration, reaching Grantown on Spey (74.9) in 10 to 12 days. All three subsequently progressed further up stream. Fishes F1 and F6 reached Lackgie (84.5) before returning to settle at Grantown. Fish F3 reached Broomhill Bridge (80.3) before going down stream a short distance to Grantown. Fish F1 remained at Inverallan House (74.9), Grantown, from 11 May until 13 September, when it progressed further up stream and entered the river Dulnain, later spawning there. Fish F6 moved up stream (in May) to reside at the mouth of the river Dulnain (78.9), where it remained until reception was lost in September.

No further signals were detected from F3 after 12 May. The initial movements of all three fish are shown in Figure 2. The complete tracks for the two fish tracked beyond May are shown in Figure 3.

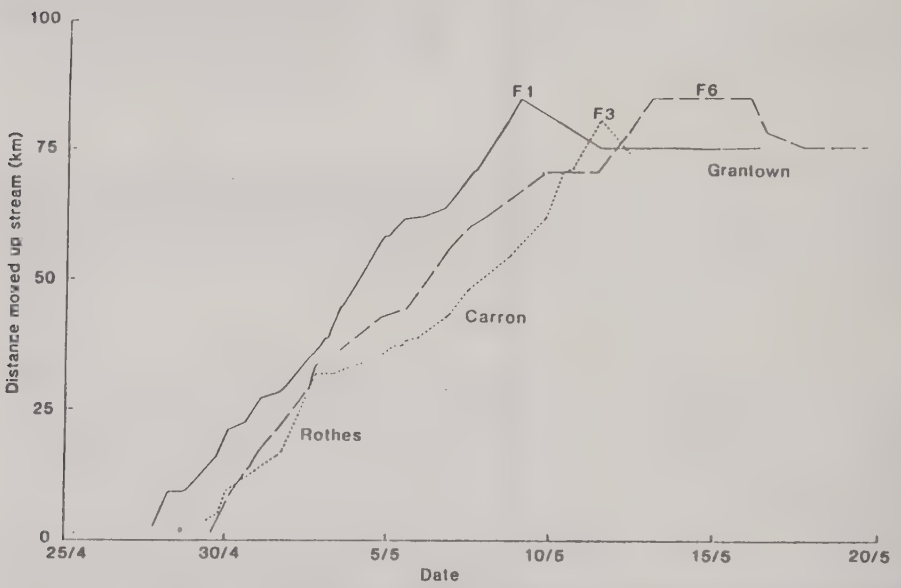

Figure 2. The initial movements up stream of fishes F1, F3 and F6. F1 and F6 reached Lackgie (85 km) while F3 reached Broomhill Bridge (80 km) before returning down stream to Grantown.

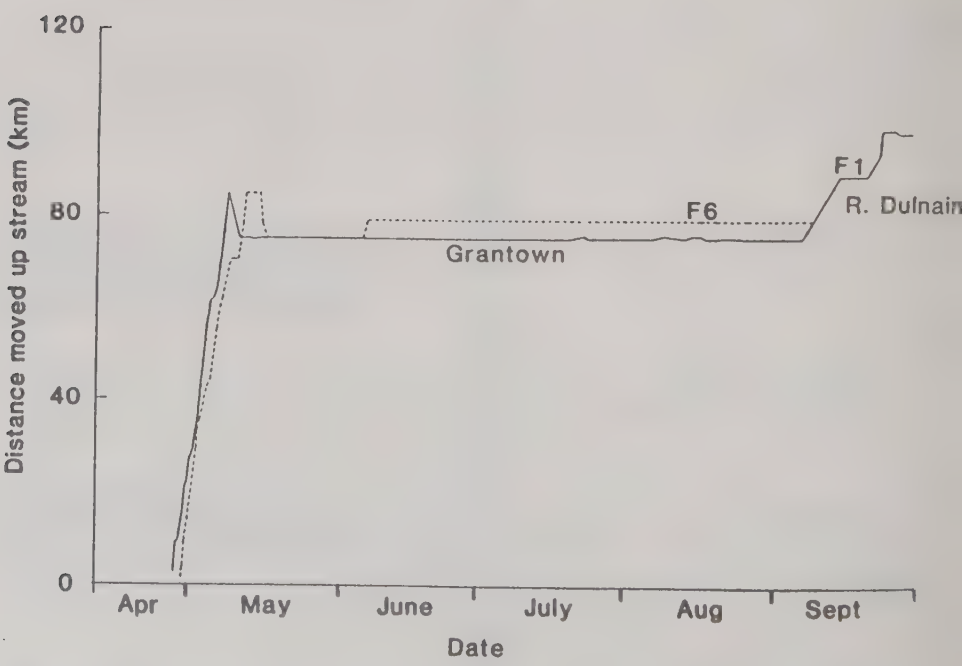

Figure 3. Up-stream migration of fishes F1 and F6. F1 entered the river Dulnain, to spawn, F6 remained at the Dulnain mouth but was eventually lost owing to tag failure.

The movements of F2 and F8 (Fig. 4) were similar in nature but they made longer stops along the way and came to rest lower in the river system. Fish F2 spent 6 days in the Aberlour Association Water (30.6), while F8 remained at Wester Elchies (34.0) for 3 days. Eventually both continued up stream to settle at Tulchan Hatchery (55.2) and Polchraine (67.4) respectively. F2 was lost in mid June while the tag from F8 was returned by an angler fishing near Grantown (74.8) in early September.

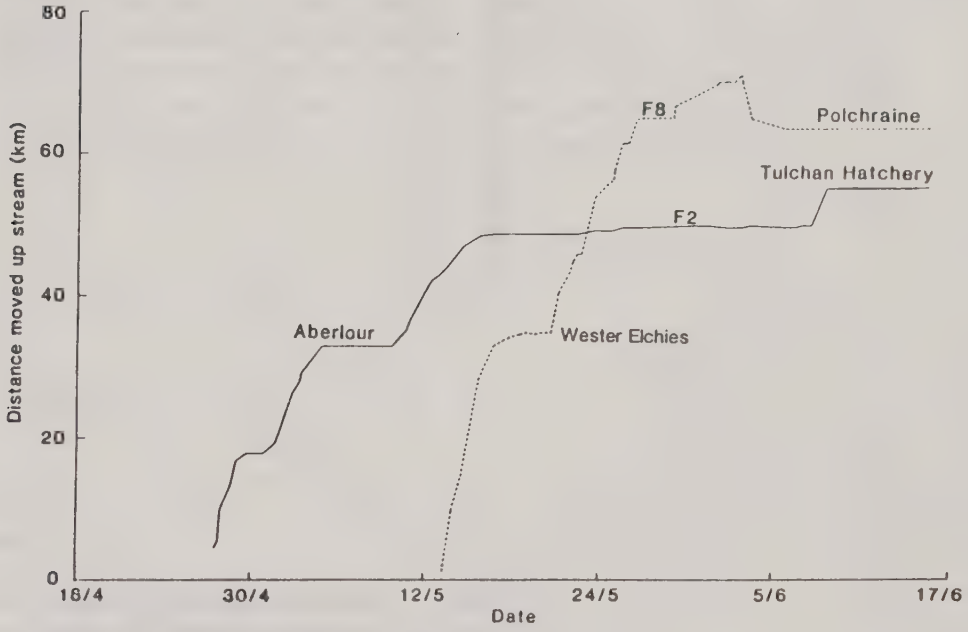

Figure 4. The initial movements up stream of fishes F2 and F8.

The other fishes in this initial batch did not move so high within the river. F5 was caught by rod and line further down stream from F8 at Arndilly (25.7), on 5 May. F4 progressed only as far as Ordiequish (10.0) on the Brae Water where it remained until early August. It seems unlikely that a fish would remain this low in the river so early in the season. It is possible that the tag was regurgitated from the stomach to lie on the river bed, the fish continuing on its way. Although it seems to be an uncommon occurrence, Solomon and Potter (1988) and McLeave *et al* (1978) noted salmon regurgitating their tags, and this has been observed twice during studies on the Dee (G.W. Smith, personal communication).

Fishes F7, F9 and F10 were particularly interesting in that they reached Arndilly Bothy Pool (25.7), Carron Bridge (38.2) and Aberlour (30.6) respectively before returning down stream and leaving the river. It is possible that these fish became diseased, though it is entirely possible that they left the river from choice. A similar movement of fish down stream was observed on the river Dee during May 1987 (G.W. Smith unpublished information), when numbers of fish were observed in a distressed state and it was confirmed from the recapture of a tagged fish that fish were suffering from furunculosis and a fungal infection.

Fishes F11—14

The second batch of four fishes, consisting of three salmon and a grilse, were released later in the year on 20 June and 24 June. Neither F11 nor F12 (both salmon) penetrated a long distance up stream. F11 reached Brae Island (9.3) before dropping back downstream to Spey Viaduct (2.0); it was eventually lost during mid August. F12 progressed to Aultdearg (11.5) where it remained from 2 July until 19 September before continuing up stream to spawn in the upper reached of Arndilly (28.2) during November (Fig. 5).

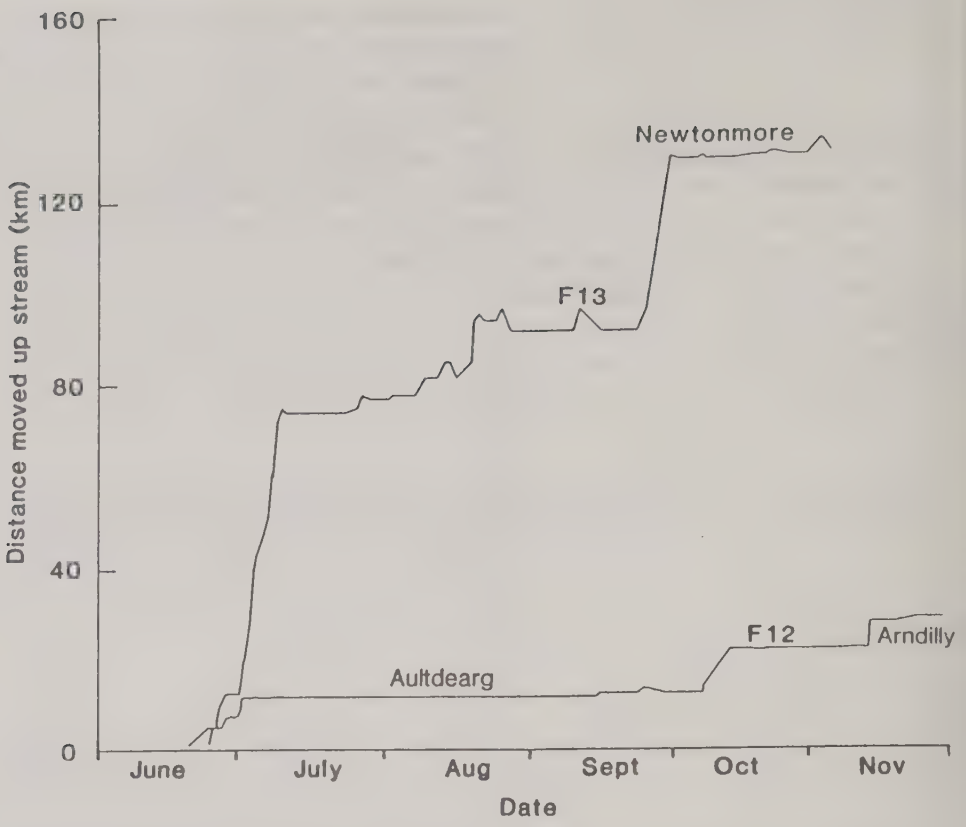

Figure 5. Up-stream migrations of fishes F12 and F13. F12 remained in the lower reaches to spawn while F13 eventually reached Newtonmore.

In contrast, F13 and F14 moved quickly up stream. F13, a grilse, reached Grantown (74.8) in 16 days. It remained in this area from 10 July until 21 August before moving up stream to Pityoulish (93.6). On 28 September it moved up stream to Newtonmore (128.8) and in late October spawned in the Spey between the Calder and Truim tributaries (132.0). Fish 14, a salmon, entered the River Avon (50.0) in July but was lost, possibly owing to tag failure, shortly afterwards.

Fishes F15–24

The final group of 10 fishes were all grilse. They were released on 5 August and 13 August. All remained in the lower reaches of the river to the end of the study period. Some remained in the pool where they had been released; for example, F20 remained in the Byres Pool (3.3) for two months. However, during September up-stream migration began towards spawning areas. The furthest migrant was F21, which reached Avonmouth (50.0). F15 remained near Baxter's Factory at Fochabers, only 7 km up stream from the release point, but the tag may have been regurgitated. Figure 6 shows the movements of three of these fish, F17, F21 and F22.

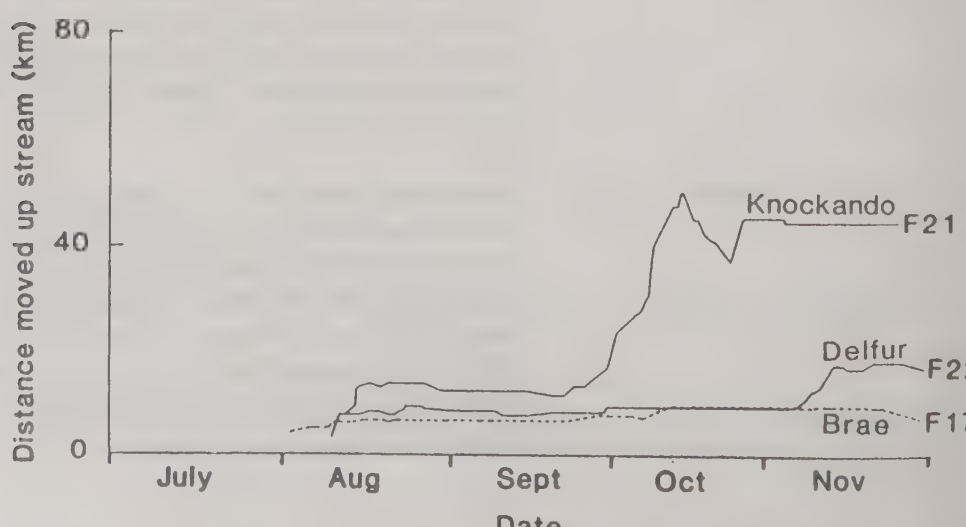

Figure 6. Up-stream migrations of the later radio tagged fishes, F17, F21 and F22.

Summary of the Movements

The summer holding positions of tracked fishes are shown in Figure 7A and the areas reached at spawning time are shown in Figure 7B. The overall pattern to emerge (Fig. 8) was very similar to that for the river Dee (Hawkins and Smith, 1986). In general, the earliest fish travelled considerable distances up stream to spawn in the higher reaches and tributaries. Later running fishes more often spawned in the lower beats. However there was considerable variability in the distances moved by fish tagged in the summer months, with F13 (a grilse tagged in June) reaching Newtonmore (128.8), while F12 (a salmon tagged only a few days before) had moved only as far as Arndilly (28.2) by spawning time. Studies on the Dee (Hawkins and Smith, 1986) have shown that some early grilse may move considerable distances up stream and join multi-sea-winter fish entering earlier in the year.

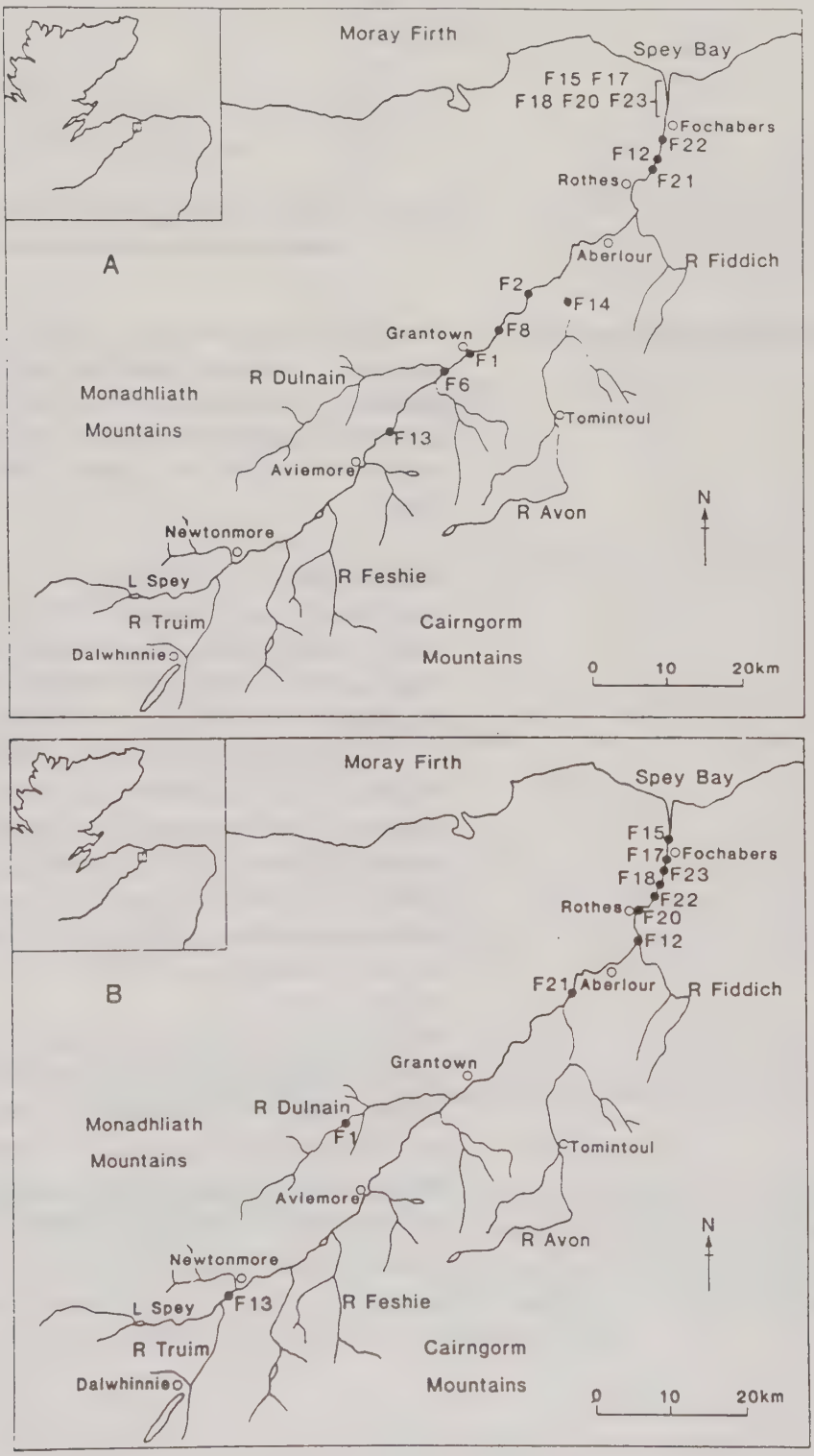

Figure 7. The River Spey and its tributaries, showing the summer holding positions (map A) and eventual spawning positions (map B).

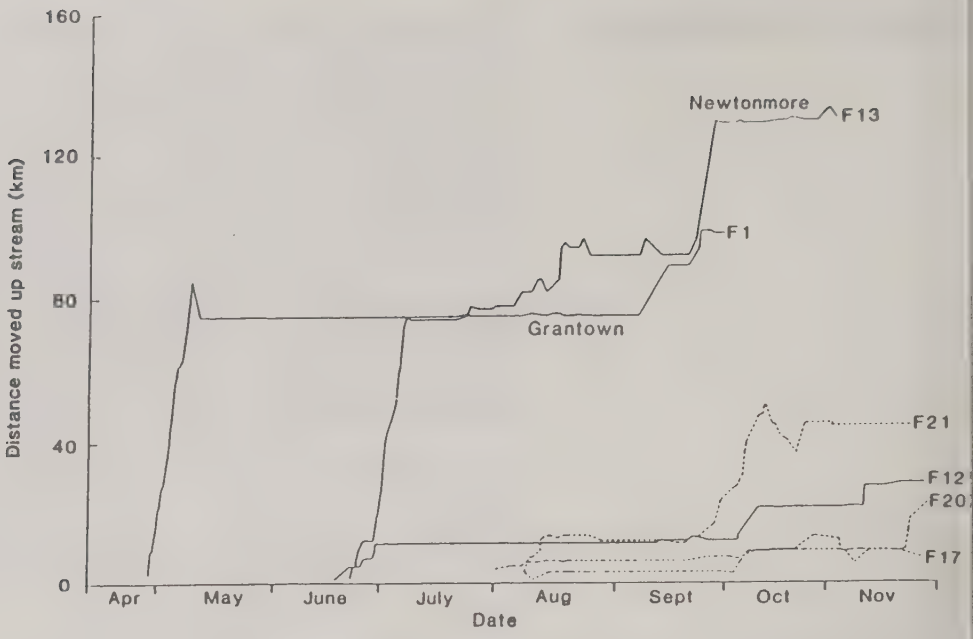

Figure 8. Summary of migrations for River Spey salmon, early fish progress further up stream than those entering later in the year.

Initial Migration into the River

After tagging, the majority of fish showed an initial period of more or less continuous up-stream migration until they settled down at the particular locations described. For the earliest fishes, F1—F14, the period of active up-stream progress varied from 10 to 14 days. During August, with F15—F24, a period of up-stream progress of only 1 to 5 days was more typical.

Figure 9 illustrates the period of day when salmon moved up stream during an active up-stream migration. The time of sunrise and sunset for the mid point of each sample period are marked on the histograms. In April and May, it appears that the fish predominantly moved up stream at night, frequently starting around dusk or later and settling in a suitable holding pool for the day. The pattern is shown in Figure 9A for the fishes released during April and May (F1—F10), which all showed a long up-stream migration. Daylight movements were recorded most notably during a period of heavy spate (when main-stem river flow exceeded 100 m^3 s^{-1} at Boat o' Brig) between 2 and 4 May. During this spate period F1, F2 and F6 were all actively migrating during daylight, though conditions were very dull owing to heavy rain and the river was turbid.

Figures 9B and 9C show the activity of those fish (F11—F24) released during June to August. With the exception of F13 and F14 these fishes made only limited upstream migrations, and the pattern is not as clear as that for F1—F10 (Fig. 9A). F13 and F14 moved mainly at night. Figure 9D shows activity during the spawning period. It is clear that the fish became more active during this time and movements were not limited to the night.

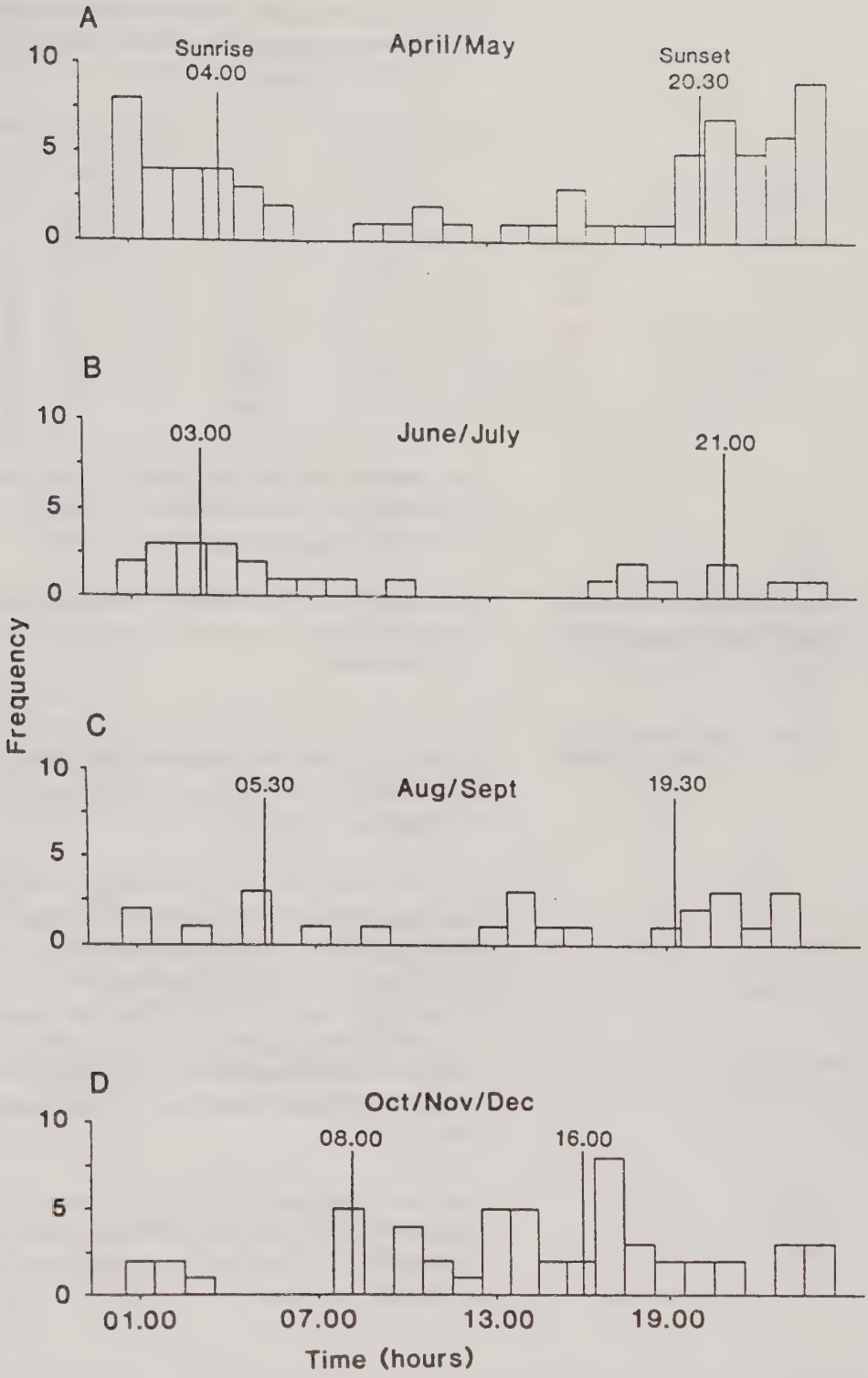

Figure 9. The time of day when fish were recorded as actively migrating up stream. The time of sunrise and sunset at the mid point of each sample period is shown.

Swimming Speeds

Where possible swimming speeds relative to the ground (that is, not corrected for the down-stream flow of the river) were calculated. Data were obtained by placing two automatic listening stations a short distance (1km to 5km) apart on the river bank and monitoring the time taken by the fish to move from one to the other. Table II gives the results obtained.

Table II Details of fishes monitored for swimming speed. The speeds given are relative to the ground. The prevailing flow conditions are given for the two nearest NERPB monitoring stations

Fish No	Distance Travelled (km)	Time (days)	Fork Length (m)	Swimming speeds			Flow rate ($m^3 s^{-1}$)	
				Km d^{-1}	m s^{-1}	bl s^{-1}	Boat o' Brig	Grantown
1	1.71	0.101	0.750	16.9	0.20	0.26	120	58
	4.32	0.292	0.750	14.8	0.17	0.23	120	58
2	1.20	0.114	0.780	10.5	0.12	0.16	120	58
8	1.69	0.045	0.765	37.6	0.43	0.57	36	17
9	1.39	0.041	0.730	33.9	0.39	0.54	33	21
10	2.07	0.125	0.805	16.6	0.19	0.23	53	25
21	3.10	0.198	0.695	15.7	0.18	0.26	47	29
	0.48	0.045	0.695	10.7	0.12	0.18	41	63

The results have been expressed in body lengths (fork length) per second to enable fish of differing size to be compared. The rates of progress vary from 0.18 body lengths (bl) s^{-1} to 0.57 bl s^{-1}.

The Effects of River Flow and Water Temperature

Flow data from the River Purification Board were matched against various fish movements to determine whether flow had significant effects on migratory behaviour.

Fish 1 : entrance to the River Dulnain

The movements of fish F1 during the period 19 July to 22 September are shown in Figure 10, together with main-stem river temperature (°C) and flow rates ($m^3 s^{-1}$) for two stations, on the main Spey at Grantown and on the Dulnain at Balnaan.

F1 spent most of the summer at Inverallan House, Grantown (74.9). During this period it was not completely inactive, several small up-stream excursions to Tarrig Mhore (75.5) were recorded. Although only taking place over a distance of 0.6 km these movements were closely associated with increases in the flow rate of the main stem Spey and the River Dulnain (Fig. 10). The river temperature throughout this period remained relatively constant. The fish eventually entered the Dulnain on the 13the of September (Fig. 10), when the tributary was in spate, and thereafter remained within the tributary.

During the period 19 July to 22 September two substantial increases in flow occurred in the main river with no major increase recorded for the Dulnain. Interestingly, F1 showed no up-stream movement on these occasions (Fig. 10(i) and (ii)).

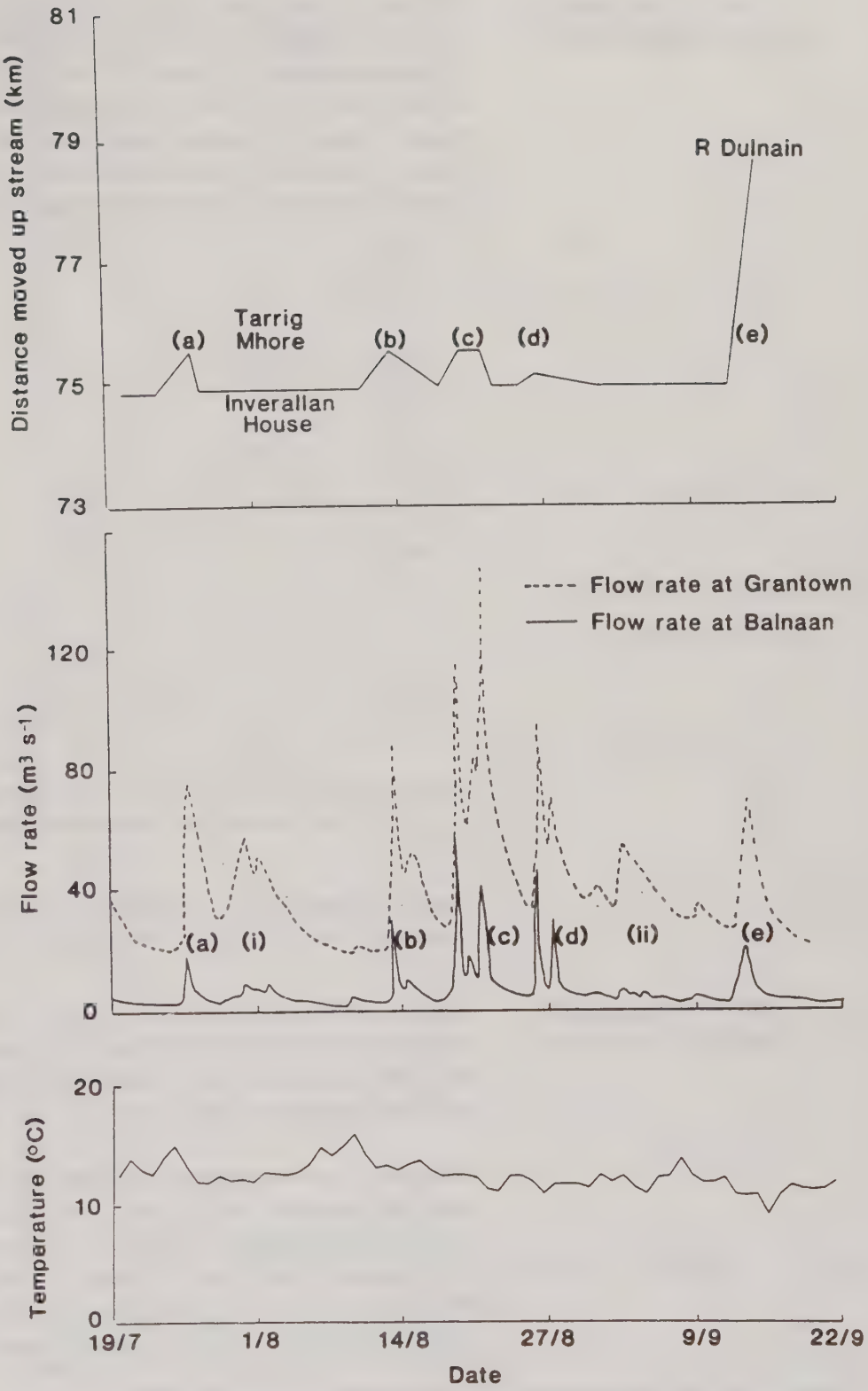

Figure 10. The movements of fish F1 during the period 19 July to 22 September, river flow ($m^3 s^{-1}$) at Grantown and in the River Dulnain at Balnaan are given, along with river temperatures (°C) from the Tulchan Hatchery. Positions (a)—(e) show spates in both the main stem Spey and the Dulnain which produced movements for Fish 1. (i) and (ii) show spates in the main stem only where no movement for Fish F1 was recorded.

Fish F6 : entrance to the River Dulnain

F6 remained at the mouth of the Dulnain from 8 June until the tag failed on 15 September. During this period it made one brief excursion into the Dulnain on 16 July, remaining there for one day. During this period the flow of the Dulnain was elevated.

Fish F14 : entrance to the River Avon

F14 entered the River Avon, one of the Spey's largest tributaries, on its up-stream migration. The flow rates in the river Avon over the period 4 July to 9 July are shown in Figure 11. Data from a listening station at Avonmouth showed that F14 entered the river between 01.35 and 02.10 h GMT on 6 July. This activity was evidently associated with a spate descending the Avon. The elevated flows recorded over this period may have provided the necessary stimulus for the fish to progress into the Avon.

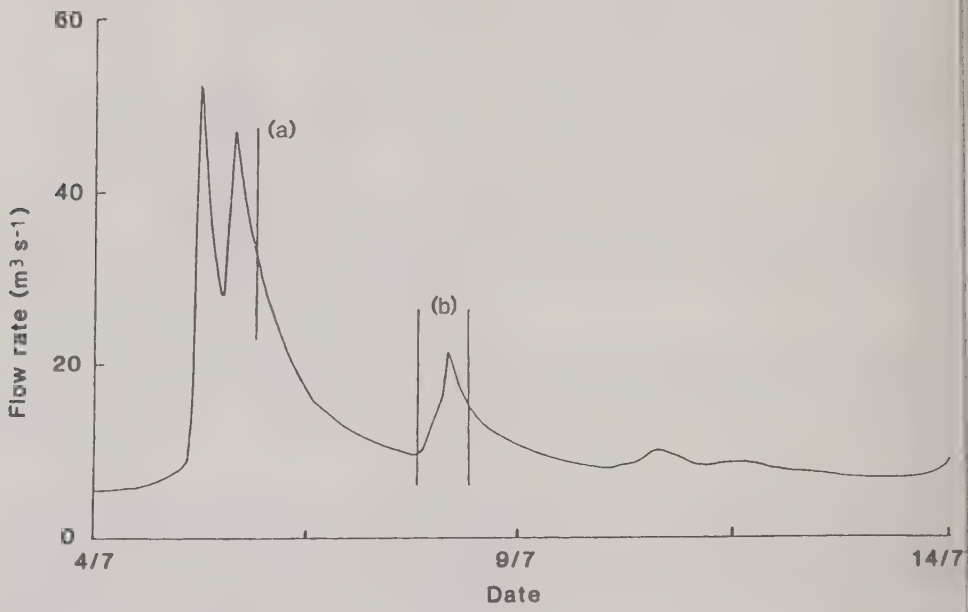

Figure 11. River flow rate ($m^3 s^{-1}$) in the River Avon. (a) Fish F14 entered the Avon at 02.00 on 6/7. (b) Further movement up stream to Delmore.

Another increase in flow occurred during 8 July, F14 then moving up-stream from Avon Bridge (51.6) to Delmore (57.1).

Fish F13 : movements within the main river

Most of the fish which were tracked remained within the Spey. Figure 12 shows the movements of F13 from 17 August to 6 October, coupled with the river temperature (°C) measured at Tulchan and flow rate ($m^3 s^{-1}$) measured at metering stations at Grantown and Kinrara.

Several of the small upstream excursions made by F1, shown in Figure 10, were also paralleled by F13 (Fig. 12). The latter movements also corresponded with increases in flow rate, though such increases did not always result in excursions. Fish 13 finally moved up to Newtonmore (128), on 28 September (Fig. 12), again at a time of increase in the main river flow. The fish eventually spawned at Newtonmore.

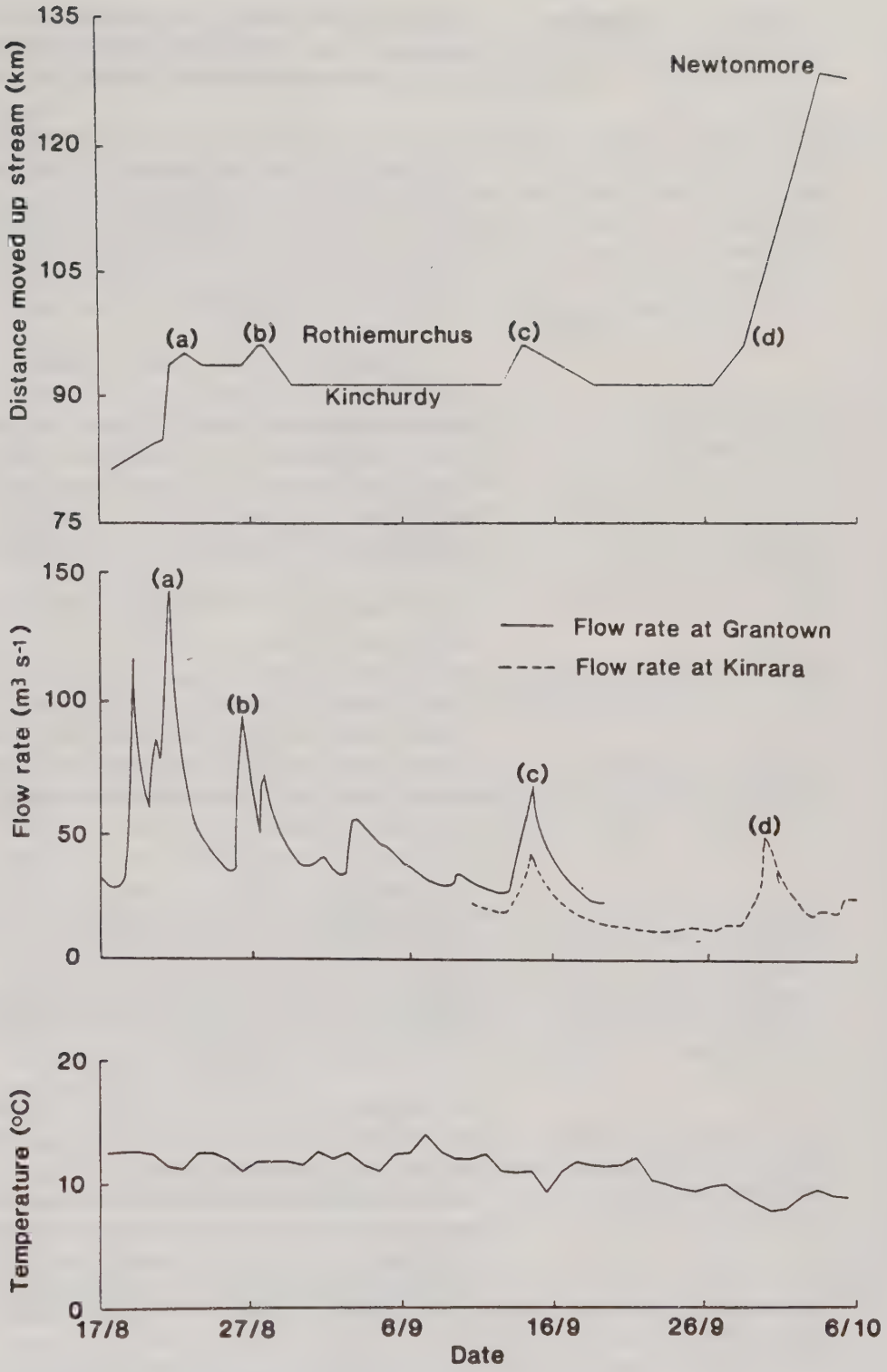

Figure 12. The movements of fish F13 during the period from 17 August to 6 October. River flows (m^3 s^{-1}) at Grantown and Kinrara are given along with river temperatures (°C) from the Tulchan Hatchery. (a), (b) and (c) show movements up stream by Fish 13 which correlate with increases in river discharge. (d) indicates movement up stream to eventual spawning area, near Newtonmore, again correlating with an increase in river flow.

Discussion

Eighteen of the twenty-four fish tagged on the Spey during 1988 migrated up stream. A small number, three fish, returned down stream after making major up-stream movements perhaps because they became diseased.

After release, the fishes which entered during the late spring, F1–10, progressed rapidly through the lower beats, often reaching Orton or Delfur (15–20) in the first 24 to 48 hours. River flow rates varies between 60 and 70 $m^3\ s^{-1}$ during these movements. Within 10–12 days these fishes had reached Grantown. They then settled in the vicinity of Grantown for the duration of the summer.

In contrast, those fishes tagged in August, F15–24, remained in the lower reaches, often close to the point where they were released (Fig. 8). Flow rates at the time of release of these fishes were between 30 and 40 $m^3\ s^{-1}$. Few conclusions can be drawn from fishes released during the low water conditions ($<24\ m^3\ s^{-1}$) which prevailed in June. Two remained in the lower beats while the others progressed up stream rapidly. It would seem that the latter, at least, were not hampered by low water conditions.

River flow rates, or at least changes in flow, have long been considered to have a major influence on the up-stream migrations and hence catches of Atlantic salmon. Huntsman (1945) noted increased angling catches during heavy freshets or spates on the Margaree River, Nova Scotia, while Hayes (1953) concluded that under favourable conditions of wind and tide salmon could be stimulated to ascend the river by both artificial and natural freshets. Banks (1969) concluded that flow was an important factor in the up-stream progress of salmon.

The salmon and grilse examined in our study on the Spey were obtained from the sweep net fishery operated in the River Spey as opposed to estuarine sweep nets or coastal set nets used in studies elsewhere (Potter, 1988; Smith and Hawkins, 1986; Brawn, 1982). As a result, no information could be gained on the role of river flow or tide in encouraging salmon into the Spey from the Moray Firth.

An apparently over-riding feature of migratory activity during the early stages after release was the time of day. Initially, during their phase of active up-stream progress, the fish tended to move at night or during dull, day-time conditions, typically the migrations starting at dusk and finishing around dawn. This pattern of acitvity has also been recorded in the river Dee (Hawkins and Smith, 1986), in the North Esk (Dunley and Shearer, 1982) and in the river Fowey in south-western England (Hellawell, Leatham and Williams, 1974).

Some variation was found in this pattern. Daylight movements were recorded on several occasions for a number of fish. This activity was closely associated with spate conditions within both the Spey and tributaries. Dunkley and Shearer (1982) have reported migrations outwith the hours of darkness during period of increased river flow.

During their initial period of active movement the rates of up-stream progress were between 0.18 and 0.57 bl s^{-1}. These values compare well with those recorded by Smith and Hawkins (1986) who found speeds of 0.24 bl s^{-1} to 0.74 bl s^{-1} for salmon within the River Dee. However, there are several problems in measuring rates of progress up stream. It is not certain that the fishes swim continuously between the two points of measurement. Moreover, slack water associated with pools and similar areas presumably offer less resistance to the fishes and might produce higher calculated speeds

for short distances. The measurements provide estimates of the average speed over ground. Actual swimming speeds through the water will of course be higher because the fishes are swimming against the current.

After the initial phase of their up-stream journey the salmon settled in holding pools. The area of the river occupied by fish varied seasonally, the earlier fish progressed substantial distances upstream, and later fishes took up residence well down the river. During their period of quiescence the fish were not completely inactive. Fishes F1 and F13 (Figs. 10 and 12) showed small up-stream movements during the summer, which were closely linked to increases in river discharge. Similar movements were not reported by Hawkins and Smith (1986), but have been described for fish in the Tay (J. Webb, personal communication).

In the case of F1, these movements were coincident with increases in flow both from the River Dulnain and in the main River Spey. However, on two occasions an increase in main river flow occurred without the corresponding increase in the Dulnain. During these floods no movements were recorded for F1. Perhaps the flow from the Dulnain, which the fish eventually entered, was the most important factor influencing the behaviour of F1. An alternative explanation, however, is that the fish moved only at very high flow rates.

Fish 13 also showed movements which corresponded with spates (Fig. 12). In this case the influence was clearly flow within the main river.

The three fishes, F1, F6 and F14, which entered tributaries, did so when there was an increase in flow. Webb and Hawkins (1989) have shown that rises in tributary discharge are a major stimulus to salmon entering the Girnock Burn, a small spawning tributary of the River Dee.

Thus, results from the Spey suggest that changes in river flow may affect the movements of salmon at certain times during the up-stream migration. This can be seen at a gross and obvious level, when the fishes enter tributaries early in the season and at spawning time, or at a more subtle level where the behaviour of a fish down stream from a confluence may be influenced by changes in discharge of the main river or of the tributary the fish eventually enters.

In future studies on the Spey it is intended that relationship between fish movements and river flow will be examined in more detail. In addition, it is hoped that by initiating tagging earlier in the year the movements and final destinations of spring salmon can be examined in greater detail.

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Summary The first years results from a radio tracking study of adult Atlantic salmon, *Salmo salar* L., ascending the River Spey are presented. They show that earlier entrants migrated further up stream to spawn than those entering later during August. Most up-stream migrations occurred during the night, typically starting at dusk and ending at dawn. Movements during daylight were nearly always associated with spate river conditions. Salmon movements were often associated with increases in river discharge; most notably in the vicinity of tributaries.

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